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TRIP REPORT:

**Lighting Research Group, Lawrence Berkeley Laboratory,
University of California, 27 February 1991**

F.E. Bartoszek

A visit to the lighting laboratory at Lawrence Berkeley Laboratory provided useful contacts and considerable information that will assist our research. The report summarizes the discussions that took place with Dr. Sam Berman and his staff.

INTRODUCTION

The lighting laboratory at Lawrence Berkeley Laboratory was established about 10 years ago, and presently has about 13 members. Their funding comes mainly from the U.S. Department of Energy, with additional funding as contracts from interested industries. Dr. Berman is the Group Leader for the lighting program and he agreed to meet with me when I was in San Francisco. Apart from Dr. Berman, I also met with Dr. Donald Levy, who works on surface wave lamps, and Michael Siminovitch, who works on efficient luminaires (lamp housings and fixtures) for fluorescent lamps.

Their program covers four areas of research:

- New light sources.
- Applications of lighting in buildings.
- Impacts of lighting on health and visual performance.
- Transfer of lighting technologies to the lighting community.

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The projects can also be classified as near-term (less than 2 years to implementation), mid-term (2-5 years), or long-term (greater than 5 years) research. Table I is reprinted from an overhead slide prepared by Dr. Berman and summarizes the major research activities of the group.

TABLE I

Lighting Research at Lawrence Berkeley Laboratory

<u>Near-term</u>	<u>Mid-term</u>	<u>Long-term</u>
• Fluorescent lamp fixtures with improved thermal and optical performance • Computer imaging of complex building interiors demonstrating efficient lighting alternatives. • Expert systems that provide detailed information for use in lighting management systems. • Assistance in lighting demonstrations, state and local outreach programs, and equipment evaluation under a variety of field conditions.	• More efficacious lighting through a new line of lamps with scotopically rich spectral output • Highly efficient phosphors for environmentally improved mercury-less lamps. • Full power chip for improved high frequency electronic ballasts for fluorescent lighting • Spectral and geometrical conditions that reduce discomfort glare in the workplace. • Portable demonstration systems suitable for technical meetings that demonstrate the various benefits of spectral control.	• Surface wave electrodeless fluorescent lamps operating at radio frequencies with 30% to 40% greater efficacies than conventional fluorescent lamps. • Low wattage capacitively coupled electrodeless high intensity discharge (HID) lamps as highly efficient replacements for high wattage incandescent and tungsten halogen lamps.

We discussed three topics during my visit: mercury isotope separation, surface wave lamps, and fluorescent lamp fixtures.

MERCURY ISOTOPE SEPARATION

Dr. Berman and his group have worked with Jacob Maya at GTE on the project of efficiency improvement in fluorescent lamps by enriching mercury with Hg-196. They have also completed a theoretical study of the process, and I received a preprint of this paper. Dr. Berman mentioned that Dr. R. Langushenko at GTE has also completed a similar study, but used a different calculation method to produce similar results. The GTE study has only been published as an internal report and is not available to us.

The conclusions from the calculation are as follows:

- Only mercury 196 contributes to the effect.
- Collisional energy exchange reactions must be included; early calculations did not include these processes and the model did not reproduce experimental results.
- The concentration of mercury-198 cannot be increased too much because there is a coincidentally large energy transfer cross section between it and mercury-196; therefore, increasing the Hg-198 concentration drains energy from Hg-196 and reduces the efficiency of the process. This observation sets constraints on any isotope separation method we select because we must not increase the Hg-198 concentration.

SURFACE WAVE LAMPS

Dr. Donald Levy works primarily with surface wave lamps. The basic principle is to attach an antenna to a lamp (e.g a standard fluorescent tube, but without electrodes) and radiate power into the lamp for operation. The radiated power travels along the inside surface of the lamp (hence the name) and excites the mercury atoms that are closest to this surface. The theoretical description is analogous to that for a coaxial cable with a lossy centre; the lamp works best when it looks like a perfect dipole antenna. Radiating power into the lamp eliminates energy losses from voltage drops across the electrodes.

The excited mercury atoms emit as usual to stimulate the phosphor. One advantage to surface waves is that they only excite the mercury atoms closest to the interior wall of the lamp, thus reducing losses from radiation trapping. The technological developments that have succeeded so far are to develop an antenna so that the lamp is instant starting (there are many other designs for antennas that efficiently couple the energy into the lamp, but the lamp must be started by a spark such as a tesla coil before it will operate), instant restarting, and has minimum reflected power.

One demonstration lamp that they had operating could use either the surface wave antenna, or conventional electrodes. A light meter on the lamp indicated that for conventional electrodes the light output was 41 (arbitrary units) as compared with 54 for the surface wave antenna, or a 30% improvement. The technical difficulties remaining to be solved are that the circuit supplying power for this lamp is only about 80% efficient, as compared to a conventional ballast, which is better than 95% efficient. In addition, each lamp has a narrow range of frequencies under which it will operate and the operating circuit must be tuned to the characteristics of each particular lamp. Since the operating frequency is about 200 MHz, the group also recognizes the potential controversy over the electromagnetic fields generated at these frequencies, both from electromagnetic interference, and from health effects. They are hoping that they will be able to obtain a dedicated frequency to use for their lamps. The trade-off in selecting a frequency is that the lower the frequency, the more efficient is the transistor used in the circuit to drive the lamp, and the higher the frequency, the better is the efficiency of the lamp itself. They estimate that the lamps will be available in the market in about five to ten years from now.

The second part of their surface wave work is on using surface waves to excite high intensity discharge lamps, which consist of mixtures of mercury, argon, a metal halide, and some xenon gas for starting. Preliminary tests on these lamps have shown that they are low wattage devices, they have good solar reproducibility, and they are instant starting and restarting. Presently, work on these lamps has been deferred by a directive from the U.S. Department of Energy.

FLUORESCENT LAMP FIXTURES

Michael Siminovitch works on designing fixtures for fluorescent lamps, so that the lamps can have optimal efficiency. Fluorescent lamps are designed to operate at 40°C; at higher temperatures the vapour pressure of the mercury increases, giving a higher vapour density of mercury atoms, which in turn increases self-absorption and decreases the efficiency of the lamp. This is especially problematic when using potted light fixtures, for example. In many cases, users have substituted compact fluorescent lamps for incandescent lamps to save energy, but because the fixture does not have adequate air circulation, the overheated lamp has degraded performance. The work in this lab is aimed at short-term studies to try to correct such problems.

The team is exploring several novel solutions to these difficulties. They have determined that it is sufficient to maintain one spot, the cold spot, on the lamp at 40°C and this will provide adequate control of the mercury vapour pressure. For example, installing compact fluorescent lamps in potted ceiling fixtures without adequate ventilation can degrade light output by 20%. Dr. Siminovitch has determined one solution to this problem which is to install thin fins on the fixture cover as a heat sink. Having the fins touch the lamp at one point controls the cold spot temperature adequately.

Other retrofit devices include Peltier coolers attached to fluorescent lamps. (Peltier coolers are essentially inverse thermocouples: by applying a voltage across a junction of two dissimilar metals, the junction either heats or cools, depending on the polarity of the voltage.) The Peltier cooler maintains a 40°C cold spot on the surface of the lamp, which in turn controls the vapour

pressure of the mercury. In their experiments, Peltier coolers running from the line power are installed into fixtures using simple devices that clip onto the lamp or touch the lamp surface in some way; the lamp installation must be sufficiently simple so that when untrained people replace lamps, the lamp automatically touches the Peltier cooler. They have seen 12-15% improvements in light output using these devices. Future developments include ideas for fabricating Peltier devices into the lamps themselves to control the cold spot temperature.

One interesting observation made by this group is that the orientation of compact fluorescent lamps is critical to proper performance. In the wrong orientation, the mercury collects in places from where it cannot easily escape, and the decrease in mercury vapour decreases the light output. In addition, most compact fluorescent lamps are attached to symmetrical bases (standard T base -- a standard incandescent lamp is on a T base), and there is no indication where the electrodes are. (In a "4-tube" compact fluorescent, two tubes contain electrodes.) In one series of experiments the group took a compact fluorescent, installed it in a horizontal fixture with the electrodes at the top, and then tilted the lamp down 3° from the horizontal. The measured light output was set at 100%; tilting the lamp up 3° from the horizontal decreased the light output to 85%. If the electrodes were set downwards, there was no change. Results such as these can have significant implications for energy conservation programs.

OTHER NOTES

- Dr. Berman is also conducting investigations into physiological effects of light. The retina senses light by two structures--cones (photopic reception) and rods (scotopic reception). Each has a different wavelength peak in sensitivity. The aim of the investigation is to try to develop new phosphors for lamps that make optimum use of these two responses and also decrease the number of lumens required for seeing. This program is still in early stages of investigation.
- The group is developing computer programs to model lighting in rooms. The inputs are the room geometry and the size and position of lamps. The program determines lighting and shadow levels throughout the room.
- There is some work on mercury-free fluorescent lamps, but so far, the efficiency is only about 50% of a conventional lamp.
- Dr. Berman mentioned that he would be willing to host a visiting researcher from Ontario Hydro who wanted to learn about establishing a lighting laboratory. Ontario Hydro would be responsible for expenses and the offer depends on approval by the U.S. Department of Energy.

LABORATORY TOUR

The following are some observations and comments noted during the tour of the lighting laboratory.

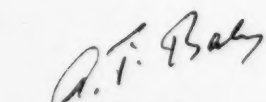
- Spectral analyses are always done in the UV from a clear lamp, because phosphor deposition is frequently uneven, and can give large variations in the light output along the length of the lamp.
- They enclose their test lamp in a box that keeps constant temperature by both heating and cooling the air. They have found that initially a lamp must equilibrate for 21 days before the light output becomes constant, and that 48 hours are required for stabilization for small temperature changes. The reason is that mercury gets trapped in different spots in the lamp and takes this long to diffuse into the bulk of the lamp.
- It is important to scrupulously avoid impurities when assembling a lamp. They find that taking the spectrum of the discharge is frequently helpful in deciding if impurities are present.
- To prepare lamps, they use a stainless steel chamber pumped both with a liquid nitrogen/molecular sieve pump, and with a liquid helium cryopump, to avoid possible contamination with pump oils. All lamps are made from quartz because it can be obtained clean, without impurities, and heated to high temperatures to remove any residual deposits.
- To add mercury to lamps: they have developed a method in which they construct helices of quartz capillary tubing (pig tails), attach these to a rack, bake them at high temperature to remove impurities, distil mercury into them, and seal them. In constructing a new lamp, they add a side tube at one end, and this tube holds one of the pig tails. They then evacuate and heat the lamp as normal, add inert gas, and seal the complete lamp assembly. When they are ready to add mercury, they shake the lamp and tube, causing the pigtail to break, and then distil this mercury into the lamp. After distillation, they tip off the side arm.
- Correct power measurements are important for proper efficiency measurements. This requires measuring the true rms voltage and the current, even though the lamp may distort the current so that it is not sinusoidal. They have also found that they must install the voltage measuring device before the current measuring instrument to avoid a spurious voltage drop in the measuring device. Clark-Hess and Valhalla both make equipment that is suitable for these measurements.
- For light measurements, they recommend a fibre optic attached to a suitable monochromator (Spex), which must be calibrated against a standard source. They also recommend that the orientation of the fibre optic cable be monitored because polarization effects can distort the light signal being measured.

- Once the spectrometer plus fibre optic have been calibrated, a secondary source can be used for routine adjustments; a GE100WHg lamp has been found to be satisfactory.

SUMMARY

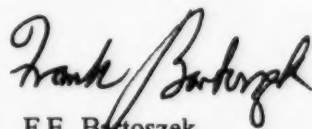
A visit to the Lighting Laboratory of Lawrence Berkeley Laboratory has provided us with substantial information on establishing our own laboratory. In addition, two unpublished reports on mercury-196 in fluorescent lamps have been invaluable in advancing our research program.

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